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THESIS

INTEGRATED SERVICES DIGITAL NETWORK (ISDN)

by

Margaretmary Torelli Weidert

June, 1985

Thesis Advisor: C. R. Jones

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This thesis contains development of a conceptual framework for an Integrated Services Digital Network (ISDN) and relates ISDN concepts to non-tactical Department of Defense (DoD) communications applications. The conceptual framework developed is non-technical and is intended to provide general management with an introduction to the ISDN. An existing model communications system, Japan's Information Network System (INS), which exhibits characteristics of ISDN, is also discussed in

terms of the conceptual framework developed. General ISDN concepts are also related to DoD applications. The Defense Data Network (DDN) is presented as a candidate network on which a potential military ISDN could be based.

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Integrated Services Digital Network (ISDN)

by

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Lieutenant Commander, United States Navy
B.E.A., University of Delaware, 1972

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN
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from the

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June 1985

ABSTRACT

This thesis contains development of a conceptual framework for an Integrated Services Digital Network (ISDN) and relates ISDN concepts to non-tactical Department of Defense (DoD) communications applications. The conceptual framework developed is non-technical and is intended to provide general management with an introduction to the ISDN. An existing model communications system, Japan's Information Network System (INS), which exhibits characteristics of ISDN, is also discussed in terms of the conceptual framework developed. General ISDN concepts are also related to DoD applications. The Defense Data Network (DDN) is presented as a candidate network on which a potential military ISDN could be based.

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LIST OF ACRONYMS AND ABBREVIATIONS

ARPANET	Advanced Research Projects Agency Network
AT&T	American Telephone and Telegraph
AUTODIN	Automatic Digital Network
AUTOVON	Automated Voice Network
CBX	Computerized Branch Exchange
CCITT	International Telephone and Telegraph Consultative Committee
CPE	Customer Premises Equipment
DDN	Defense Data Network
DoD	Department of Defense
FCC	Federal Communications Commission
FDM	Frequency Division Multiplexing
IDN	Integrated Digital Network
INS	Information Network System
ITU	International Telecommunications Union
NCTE	Network Channel Terminating Equipment
NTT	Nippon Telegraph and Telephone Corporation
OSI	Open Systems Interconnection
PCM	Pulse Code Modulation
POM	Program Objective Memorandum
POTS	Plain Old Telephone Service
TDM	Time Division Multiplexing

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I. INTRODUCTION

A. PURPOSE

The purpose of this thesis is to develop a conceptual framework for an Integrated Services Digital Network (ISDN) and relate ISDN concepts to non-tactical Department of Defense (DoD) communications applications. The framework developed will be non-technical and is intended for use by general management as an introduction to the ISDN.

B. BACKGROUND

The International Telegraph and Telephone Consultative Committee (CCITT) of the United Nations' International Telecommunication Union (ITU) defines ISDN as:

> "A network evolved from the telephone network that provides end-to-end digital connectivity to support a wide range of services, including voice and non-voice services to which users have access by a limited set of standard multipurpose customer interfaces." [Ref. 1: p. 27]

Non-voice services include the broad categories of data, text, and imagery. [Ref. 2: p. 79] The National Telecommunications and Information Administration (NTIA) parallels the ISDN to "a shopping center of tomorrow... [whose] success...is based on...the desires of people to have a sole supplier for their services." [Ref. 3: p. 95]

Recent American Telephone and Telegraph (AT&T) marketing literature has stated that, with ISDN, users will be able to

access a network as easily as using "today's modular phone jack and [ISDN will be] as compatible with different equipment designs as an ordinary electrical outlet." [Ref. 4: p. 60]

The ISDN is a concept evolving out of current telephone technology [Ref. 5: p. 12] and it is estimated that one to two decades will be required to complete the transition. [Ref. 6: p. 8] This evolution is expected to occur as a natural extension of the digital transmission and switching technologies of telephone Integrated Digital Networks (IDN's). [Ref 5: p. 12] As early as 1981, ISDN was considered to be

> "...the ultimate goal of present telecommunications network evolution, combining voice and a wide range of non-voice services on a common network utilizing digital transmission and switching. Digital exchanges...will ensure a smooth transition from the present analog network, through the integrated digital network, to a future ISDN." [Ref. 7: p. 2]

C. METHODOLOGY

To develop the ISDN conceptual framework, a search of the current literature including periodicals, technical journals, and technical books, was conducted. Pre-ISDN systems were studied to trace the evolution toward ISDN along with a review of the technologies influencing the evolution toward ISDN.

Model integrated digital networks exhibiting ISDN characteristics were investigated to understand existing system configurations. Interviews were conducted at

National Communications System offices in Arlington, Virginia.

D. SCOPE

The emphasis of the thesis will be to develop a non-technical conceptual framework for the ISDN. Relevant technologies in the development of ISDN will be discussed to the degree necessary for background information.

The thesis will not make <u>specific</u> ISDN recommendations for the DoD. It will, however, present ISDN concepts for consideration in non-tactical DoD applications.

E. THESIS ORGANIZATION

Chapter I provides an introduction to the thesis. It describes the purpose, background, methodology, and scope of the thesis.

Chapters II through VI give background and develop the conceptual framework for ISDN. Chapter II provides background material on technologies leading to the ISDN; concepts and objectives are presented and some political and technological issues discussed. Chapter III contains a description of the emerging technologies which make ISDN feasible for multipurpose communications. Chapter IV contains a discussion of the relationships of the telecommunications carriers, equipment suppliers, and users of the ISDN. Chapter V contains a discussion of the

features of ISDN, as applied to the conceptual framework developed.

Chapter VI contains a description of an experimental network with characteristics of an ISDN. Chapter VII contains a description of the ISDN concepts which may be applicable to non-tactical DoD communications.

Chapter VIII contains a discussion of some issues which must be resolved before global ISDN's can exist. It also contains a summary of the evolution toward ISDN. Existing IDN features which will facilitate the gradual transition from IDN to ISDN are discussed. Potential DoD applications are also summarized.

II EVOLUTION TOWARD AN ISDN

A. BACKGROUND

"Historically, analog transmission has dominated the telecommunications industry since its inception." [Ref. 8: p. 104] Analog, or continuous, signals typically transmit voice while digital, or discrete, signals are required for most data communication. [Ref. 9: p. 18] The transmission of an analog signal requires amplification because the signal weakens with distance. Any noise that accompanies the signal is also amplified. Digital signals, however, are repeated periodically during transmission and data integrity is maintained. For transmitting data in its binary format, digital systems usually exhibit lower error rates than analog systems because of the periodic signal regeneration during transmission. [Ref. 8: p. 104]

Other advantages of digital transmission are that a variety of services, such as voice, data, and facsimile, can be multiplexed for more efficient equipment usage; much higher data rates utilizing existing lines are also possible. "As the cost of digital computers and integrated circuit chips continues to drop, digital transmission and its associated switching is likely to become much cheaper than analog transmission as well." [Ref. 8: p. 105]

The idea of an integrated digital network (IDN), where digital transmission and switching functions are integrated, was proposed by Vaughan of the Bell System in 1959 and "is in the process of being implemented worldwide." [Ref. 10: p. 538] The IDN will

> "combine the coverage of the geographically extensive telephone network with the data carrying capacity of digital data networks in a structure called ISDN where 'integrated' in ISDN (as differentiated from IDN) refers to the simultaneous carrying of digitized voice and a variety of data traffic on the same digital transmission links and by the same digital exchanges. The key to ISDN is the small marginal cost for offering data services on the digital telephone network, with virtually no cost or performance penalty for voice services already carried on the IDN." [Ref. 7: p. 2]

The ISDN is expected to be the next step in the evolution beyond IDN. As stated by Kostas, [Ref. 5: p. 12]

> "ISDN's will be based on the concepts developed for telephone Integrated Digital Networks (IDN's), and may evolve by progressively incorporating additional functions and network features, including those of other dedicated networks such as circuit-switching and packet-switching for data, so as to provide for existing new services."

B. KEY OBJECTIVES AND ATTRIBUTES OF ISDN

The development of a worldwide ISDN has involved the efforts of many national governments, standards organizations, and equipment manufacturing companies. Certain common objectives of an ISDN are shared by the various groups and these key objectives are listed by Stallings [Ref. 10: p. 540] as:

> "Standardization: It is essential that a single set of ISDN standards be provided to permit universal access and to permit the development of cost-effective equipment.

Transparency: The most important service to be provided is a transparent transmission service. This permits users to develop applications and protocols with the confidence that they will not be affected by the underlying ISDN.

Separation of competitive functions: It must be possible to separate out functions that could be provided competitively as opposed to those that are fundamentally part of the ISDN. In most countries, a single, government-owned entity will provide all services. Some countries desire (in the case of the United States, require) that certain enhanced services be offered competitively (e.g., videotex, electronic mail)....

Leased and switched services: The ISDN should provide dedicated point-to-point services as well as switched services. This will allow the user to optimize his or her implementation of switching and routing techniques.

Cost-related tariffs: The price for ISDN service should be related to cost, and independent of the type of data being carried. One type of service should not be in the position of subsidizing others.

Smooth migration: The conversion to ISDN will be gradual, and the evolving network must coexist with existing equipment and services. Thus ISDN interfaces should evolve from current interfaces, and provide a migration path for users.

Multiplexed support: In addition to providing low-capacity support to individual users, multiplexed support must be provided to accommodate user-owned CBX [computerized branch exchange] and local network equipment."

While the objectives stated above should not be considered as an all-inclusive list, they represent the major considerations which are forming the development of the ISDN.

The CCITT, which serves as the controlling body for ISDN standards, defines the ISDN through the following six attributes: [Ref. 10: p. 535]

"1. The ISDN is to evolve from the existing telephone networks, which themselves are evolving into integrated digital networks.

2. New services introduced into the ISDN should be compatible with the basic 64 Kbps switched digital connections.

3. The ISDN will require from 10 to 20 years (from the early 1980's) for full transition.

4. During the transition, the ISDN will rely on internetworking among the national ISDN's and other non-ISDN networks (such as public data networks).

5. The ISDN will contain intelligence for the provision of service features, maintenance and system control, and network management.

6. The ISDN will use a layered functional set of integrated protocols for the various access arrangements."

These six attributes are guiding the development of standards related to signaling, network interfaces, and protocols. [Ref. 10: p. 545]

C. CCITT INVOLVEMENT IN ISDN

The CCITT is one of seven organs of the International Telecommunications Union, an agency of the United Nations. The CCITT

> "attempts to promote and ensure the operation of international telecommunications systems...by issuing Recommendations (or standards) for end-to-end performance, interconnection, and maintenance of the world networks for telephone, telegraph, and data communication." [Ref. 9: p. 67]

Fifteen study groups review the recommendations over a designated three year period. The recommendation cycle is described in detail in NTIA Report 83-138. [Ref. 9: App. A]

The Digital Networks study group (SG), SG XVIII, is the "principal coordinating body for CCITT ISDN standards activities." [Ref. 10: p. 547] Key areas addressed by other study groups which influence SG XVIII are telephone operation and quality of service (SG II), transmission maintenance (SG IV), data communication networks (SG VII), telephone switching and signaling (SG XI), and data communication over the telephone network (SG XVII).

In this country, the United States CCITT Organization is "advisory to and under the jurisdiction of the Department of State." [Ref. 9: p. 70] The U.S. CCITT channels U.S. interaction with the international CCITT and has four main functions: to offer a forum for the telecommunications industry for "participation in the standards-making process;" to serve as an "arena for discussion and debate" prior to "development of U.S. positions and contributions;" to provide "guidance for delegates at the international meetings;" and to serve as a "pool" of representatives from the private sector who can be selected for the U.S. delegation staff. The U.S. CCITT admits members from "industry, government agencies, scientific organizations, user groups, and standards groups." [Ref. 9: p. 71]

D. POLITICAL AND TECHNICAL ISSUES

There are many issues associated with the evolution toward ISDN. The issues may be categorized as international

and national with policy-oriented (political) and technical issues in each category. [Ref. 9: p. 52]

International policy issues arise from the "desire for national sovereignty." They include national security and survivability, privacy and industrial development, foreign competition and market protection in international trade, standards which do not conflict with national policy, protection of cultural identity and sovereignty, and fair and equitable regulation of routing and tariffs. [Ref. 9: p. 52]

On the international scale, technical issues arise from the "need for universal, affordable services." Interfacing the various national networks, necessity of a common scheme for addressing, effect of signaling and digitization on defense posture, general standards development, and perceived quality of service are the primary issues under discussion. [Ref. 9: p. 52]

There are some national issues which are unique to the pro-competitive nature of business in the United States. Competition and deregulation in industry serve to induce profit and expand the marketplace. These issues include ownership and control of telecommunications functions, network or terminal location of certain intelligence functions, impact of new technologies, interconnection of multiple networks in an ISDN structure, the distinction

between basic and enhanced services, and the type of user access. [Ref. 9: p. 53]

A diversity of new technologies is created in a competitive market environment. Technical issues are interconnection among multiple ISDN's, traffic distribution over specialized networks, performance and quality of service ratings, treatment of technological advances, and user access and management. [Ref. 9: p. 54]

E. SUMMARY

A discussion of the relative performance characteristics of analog and digital systems was presented as background for the evolution toward IDN's. ISDN is the 'ultimate goal' of the present telecommunication network evolution. Objectives and attributes of ISDN were presented. The role of the CCITT, the key organization in the development of ISDN standards, was discussed. Political and technical issues at both international and national levels were summarized.

III. ISDN SERVICES AND TECHNOLOGIES

A. PURPOSE

The purpose of this chapter is to describe the various services of an ISDN. Background information on the technologies supporting the ISDN concept will also be discussed. A generalized framework of the Open Systems Interconnection (OSI) Reference Model and integrated digital networks is presented.

B. DESCRIPTION OF SERVICES

> "The ISDN, first of all, is not equipment. It is a capability for providing expanded and advanced services to customers. Equipment will have to be developed so that new communication services can be made available to a broad base of users." [Ref. 11: p. 45]

The existing, expanded, and advanced services may be broadly categorized as either voice or non-voice. Voice service is primarily telephone, with future services expanding to include information retrieval using voice recognition and speech synthesis. Non-voice services include digital data, text, and imagery. [Ref. 10: p. 544]

Examples of digital data services are telemetry, funds transfer, information retrieval, mailbox, electronic mail, alarms, and, at higher data rates, high-speed computer communication. [Ref. 10: p. 544] Although most of these services already exist, some, such as telemetry and alarms,

can be upgraded using digital techniques. [Ref. 12: p. 19]

Existing text services include telex and electronic mail. The new services planned for public networks include teletex and videotex. Teletex is "a service which provides communication between terminals which are used for the preparation, editing, and printing of correspondence." [Ref. 12: p. 29] Videotex is "a databank enquiry and retrieval service, also allowing for transactional facilities." [Ref. 12: p. 29]

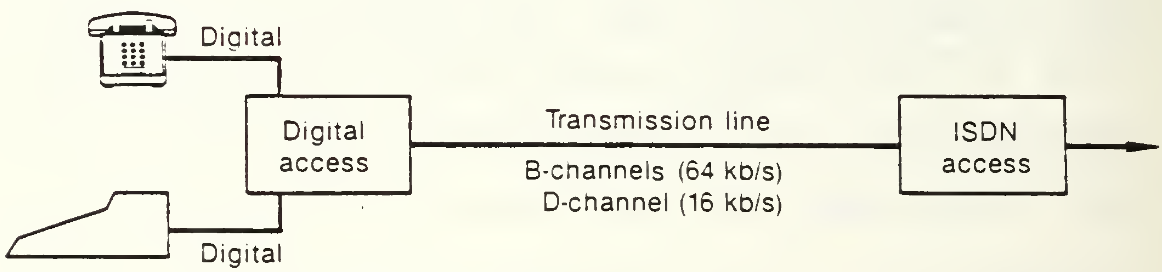
Another new service, facsimile, is the image service provided at 64 Kbps (thousand bits per second). Facsimile is "a system which allows the transmission and hard copy reproduction of fixed images (photographic or otherwise) using a scanning technique." [Ref. 12: p. 29] Future image services such as teleconferencing will require higher data rates. [Ref. 10: p. 544]

C. MEDIA

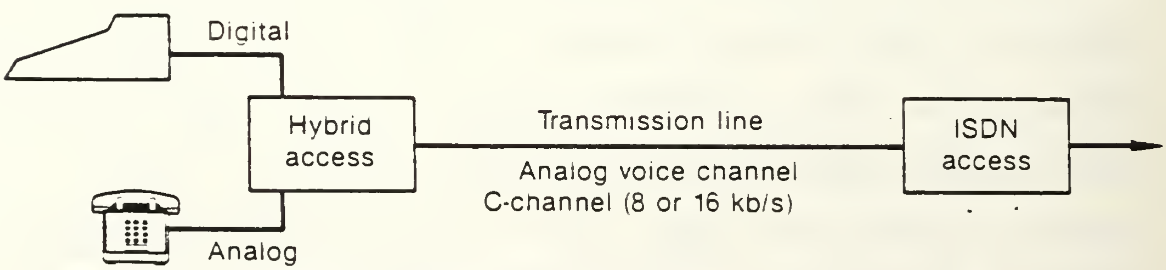
The T-1 Digital Carrier System, introduced for commercial use in 1962 by AT&T, is the "most widely used transmission system at present with time division multiplexing (TDM)...[The T1 carrier] uses wire pairs with digital repeaters." [Ref. 13: p. 275] Twenty-four speech channels are encoded into a bit stream through pulse code modulation (PCM) and TDM. This is "used for short-haul

transmission over distances of up to 50 miles." [Ref. 13: p. 275]

The basic channel structure is composed of two 64 Kbps information channels (called B channels) and one 16 Kbps signaling channel (D channel). This basic structure is referred to as 2B + D. Since a consensus has not been reached on standardization, other types of channel structures may be used. For example, primary access uses a B + D configuration, while hybrid access accommodates an analog channel of 4 KHz (A channel) and a digital channel of either 8 or 16 Kbps (the C channel; a dispute exists between the U.S. and Japan over the bit rate). [Ref. 10: p. 549]



(a) B-and D-channels for ISDN



(b) Analog and C-channels for ISDN (interim)

Figure 3-1 ISDN Channel Structure Configurations

Figure 3-1 (a) and (b) displays configurations for ISDN channel structures. [Ref. 10: p. 549]

D. SWITCHING

There are three types of communications switching. Each has its own advantages and disadvantages for its particular communications applications.

Message switching uses a message store-and-forward system, where the entire message is received, briefly stored, then sent to the next node. Dedicated paths are not established and the destination address is contained in each message. [Ref. 10: p. 566]

In circuit switching, a dedicated end-to-end communications path is established. The telephone system utilizes circuit switching. There are circuit switching applications in digital networks for voice services. [Ref. 14: pp. 28,32]

In packet switching, messages are divided into small blocks of data. These 'packets' are then "transmitted as in message switching. Usually, packet switching is more efficient and rapid than message switching." [Ref. 10: p. 567]

E. DIGITAL PIPE

Stallings describes the 'digital pipe' as the local interface through which a user can access ISDN. Such pipes will be of different sizes and particular bit rates for the

variety of user needs. "The pipe to the user's premises has a fixed capacity, but the traffic on the pipe may be a variable mix up to the capacity limit." [Ref. 10: p. 539] In other words, a residential user may desire only telephone service, requiring a lower capacity pipe than a commercial user, who may require a larger pipe to accommodate several services. Figure 3-2 displays a conceptual view of ISDN interconnections. [Ref. 10: pp. 539-40]

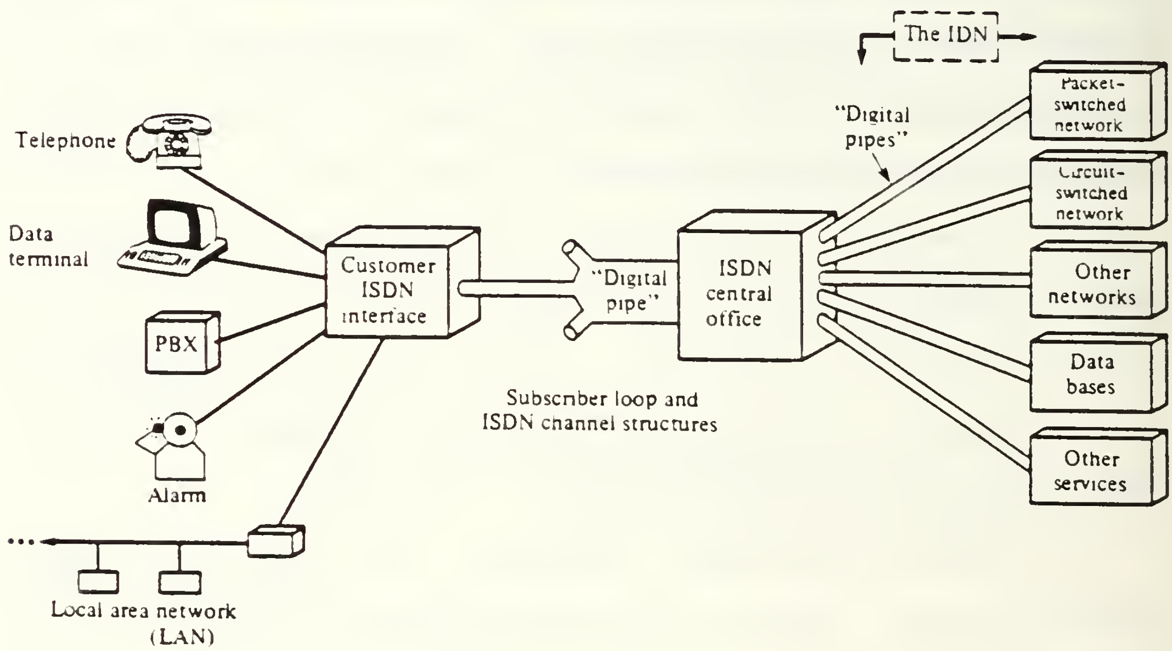


Figure 3-2 Conceptual View of ISDN Interconnections.

F. OPEN SYSTEMS INTERCONNECTION (OSI) MODEL

The International Organization for Standardization (ISO), in 1977, established a subcommittee to develop a structure or architecture that defines the communications tasks between applications on different computers. This recognized the need that before standards could be developed

there must be a common structure or architecture. As a result, the Open Systems Interconnection (OSI) Reference Model was created as a "framework for defining standards for linking heterogeneous computers." [Ref. 10: p. 386] The open architecture of this model "provides the basis for connecting open systems" and allows any two systems "conforming to the reference model and the associated standards to connect." [Ref. 10: p. 386]

In 1982, the ISO formally accepted the OSI Reference Model. [Ref. 3: p. 64] This model has been widely accepted because it provides both a framework for developing standards and structure for discussing communications system design. "Virtually all standards activities for communications are proceeding within OSI model. Government customers and most private customers will demand OSI compatibility. The industry must conform." [Ref. 10: p. 394]

G. INTEGRATED DIGITAL NETWORK (IDN)

In 1959, H.E. Vaughan of Bell Laboratories proposed the idea that digital transmission and digital switching functions could be integrated. [Ref. 15: p. 909] AT&T introduced the digital T-carrier system in 1962 (digital transmission) and Western Electric introduced the 4ESS in 1976. The 4ESS electronic switch was the "first large-scale, time-division digital switch." [Ref. 2: p. 68]

Figure 3-3(a) [Ref. 10: p. 539] shows that with nonintegrated transmission and switching of analog voice signals, a series of modulation/frequency-division multiplexing (FDM) and demodulation/demultiplexing processes occur at each switching center along the path. Noise and cost accumulate each time this occurs. [Ref. 2: p. 70]

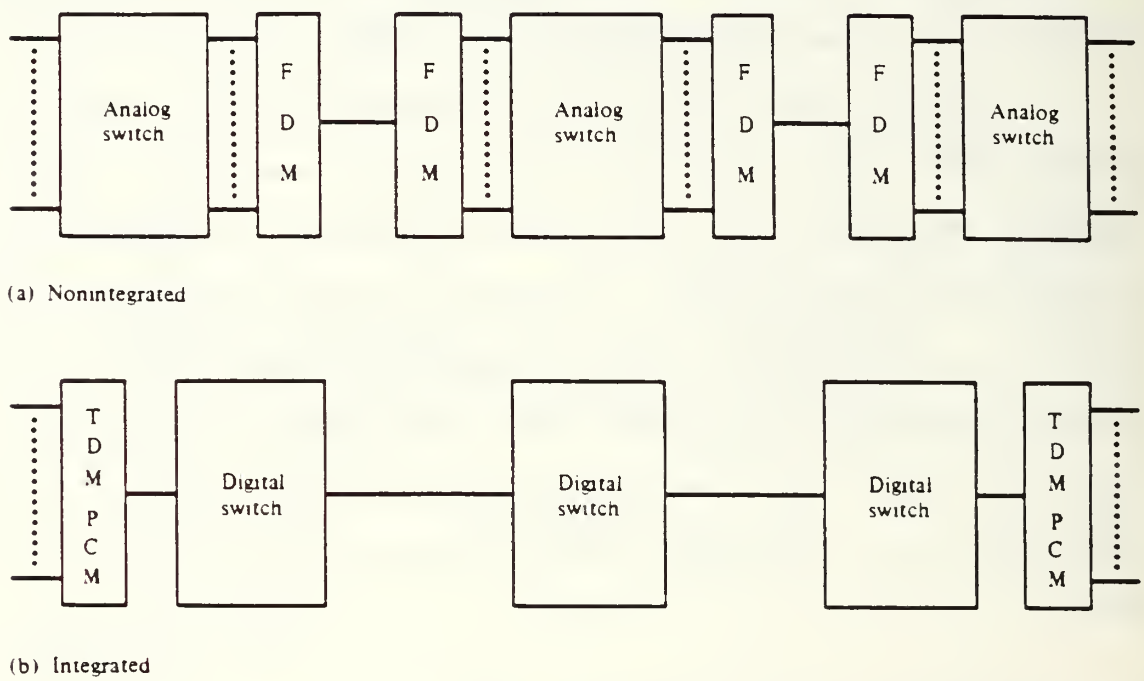


Figure 3-3 Transmission and Switching in Nonintegrated and Integrated Networks.

As shown in Figure 3-3(b) [Ref. 10: p. 540], in an integrated network, the transmission and switching systems are both digital. The incoming analog voice signals are digitized using PCM and multiplexed using TDM. There is no noise increase over the line since the signals do not require decoding at each switch. The multiplex/demultiplex

functions are incorporated into the digital switch. [Ref. 2: p. 70]

The integrated network described above operates once a signal is received at a switch. The next step for voice is digitization at the customer premises, leading to an end-to-end switched digital telecommunication network. Such an integrated digital network will not only provide economical voice communication, but also will serve the increasing diversity of digital data services. [Ref. 2: p. 70]

This IDN "will combine the coverage of the geographically extensive telephone network with the data carrying capacity of digital data networks." [Ref. 10: p. 539] The result will be an ISDN, where digitized voice and several types of data traffic are simultaneously carried on the "same digital transmission links <u>and</u> by the same digital exchanges." [Ref. 7: p. 2]

H. SUMMARY

Before describing the ISDN concept, it was necessary to define the various services which will comprise an ISDN. It was also important to provide some background information on the technologies and architecture used to build the framework. Finally, the IDN development was presented as the step under development which will be the bridge to the ISDN.

It is anticipated that during this decade digital transmission and digital switching technologies will fuse to produce an IDN where "connections established by digital exchanges will be used for transmission of digital signals for a signal service such as [but not limited to] telephony." [Ref. 6: p. 4]

IV. ISDN SYSTEM COMPONENTS

A. PURPOSE

The purpose of this chapter is to explain the roles and interactions of the communications carriers, equipment manufacturers, and users. These components often have competing demands and will influence the development of ISDN standards.

B. CARRIERS

Carriers, or telecommunications vendors, generally support the concepts of ISDN. Since many of the digital components are in place, most vendors feel ISDN "will fit neatly into what is already installed." [Ref. 1: p. 29] Carriers will tend to favor dumb terminals which will allow them the opportunity to provide enhancements on the lines. [Ref. 1: p. 31]

In February, 1985, AT&T Network Systems announced its Universal Information Services, an integrated network architecture, initially aimed at serving business customers. With this public announcement, AT&T voiced its support of ISDN, by stating its advantages in access and compatibility and by discussing its new technologies, such as the 5ESS digital electronic switch. [Ref. 4: p. 61]

AT&T and other vendors of telecommunications services and equipment favor ISDN because it offers potential for

major cost reductions. These cost reductions can be realized through a reduced need for analog/digital transformation, reduced call set up times, reduced call holding times for data transmission and the fact that extensive digital switching technologies are currently in use. [Ref. 1: p. 29]

Similarly, the divested regional Bell Operating Companies (BOC's), also favor ISDN. In addition to the cost reductions anticipated by AT&T Communications, the BOC's will be able to increase the use of their existing cable plant significantly because transmissions on the local loop will be at the higher digital speeds. [Ref. 1: p. 29] Recognizing these potential benefits, Pacific Telesis has announced its willingness to "set a new standard for the telecommunications industry worldwide" by applying for patents on digital loop technology to provide for ISDN. [Ref. 16: p. 4]

C. EQUIPMENT

Until a consensus of standards is reached, the types of termination equipment to be used in the ISDN cannot be determined. It has been difficult to determine standardization in a competitive situation. The telecommunications carriers favor 'dumb' terminals, called network channel terminating equipment (NCTE) with enhanced capabilities on the network lines. The equipment manufacturers favor intelligent terminals, or customer

premises equipment (CPE), with the enhancements available for each specific terminal type. [Ref. 1: p. 31]

The NCTE's provide customer access from standard terminal types to the ISDN. With the NCTE, there would be "stability of the interface" which would provide the "integral part of the network." [Ref. 17: p. 46] The network dumb terminals require the sophistication of the network to be provided in the lines, where bandwidth considerations determine the capacity and speed of the network. [Ref. 1: p. 31] Technical descriptions of options for early NCTE's are detailed by Griffiths' article, "ISDN Network Terminating Equipment." [Ref. 18]

CPE's include all types of terminal interfaces, from telephones to microcomputers. They are user and application specific, add value to a system, and should be profit making for the hardware vendors, who wish to enhance their equipment "at the expense of the telecommunications bill." [Ref. 1: p. 31]

Mainframe vendors not directly involved in the provision of telecommunications products are less than enthusiastic about ISDN. Mainframe vendors anticipate a loss of terminal sales because with the standard interfaces and protocols of the ISDN, users would tend to be less dependent on their mainframe vendors for terminals. Computer vendors "sell boxes, whether they are mainframes or terminals." [Ref. 1: p. 31]

D. USERS

Users, or customers, can be categorized as residential or commercial (including government). Residential requirements are typically less sophisticated than the service demands of a business establishment.

The end-to-end capability of ISDN will provide access to any user. User access will be accomplished through a terminal interface with the network, which has yet to be standar zed. Until ISDN is implemented, access will be determined by terminal t e. [Ref. 18: p. 214]

Specific, quantifi e user needs are unknown at this time. However, various market studies have identified some generic needs and perceived benefits. [Ref. 19: p. 48]

User needs include cost control, agreed standards with stable interfaces, flexibility, network interworking (interoperability), transparency, management, efficient network utilization, security, and call management. Benefits include control of network costs, new terminal multifunctionality, extension of existing terminal functionality, network intelligence, and ubiquity. [Ref. 19: p. 48]

E. SUMMARY

Competing demands of the carriers, equipment suppliers, and users will continue to be issues in determining the level of standardization within the conceptual ISDN

framework. As the evolution toward ISDN progresses, interfaces must become standardized for the true potential of ISDN to be realized.

V. ISDN FEATURES

A. PURPOSE

The purpose of this chapter is to describe the projected features in the ISDN conceptual framework. These features are considered necessary to support user needs in the end-to-end network and will be used in the discussion of a model system in the next chapter.

B. STANDARDIZATION

A goal of the ISDN is for cost-effective, ubiquitous user access "through a limited set of standard multipurpose network connection types and interfaces." [Ref. 5: p. 11] Standardization is the key to the universal accessibility of ISDN. It is also one of the major problems being faced in the development of the ISDN concept.

Presently, the U.S. regulatory posture is in conflict with the intent of the CCITT standards for 'universal compatibility in equipment and services.' The dispute is over the location of the line of demarcation between the network and the user interface. The proposed CCITT ISDN standard requires a network termination 'box' at the user end to transmit and receive digital information to and from the local switching center. The FCC does not consider this box to be part of the public network, but part of the CPE. This would make the U.S. interface different with those of

other countries, who concur with the CCITT view of the interface as part of the network itself. [Ref. 20: p. 47]

The benefits of standardization include connectivity and interoperability. "The existence of information paths among a population of users is measured by connectivity. The existence of interface and protocol compatibility...is measured by interoperability." [Ref. 21: p. 9] Both connectivity and interoperability are essential to improved accessibility.

C. RELIABILITY

Greater reliability is one of the major advantages of digital technology, as envisioned in ISDN. The quality of digital signals transmitted over long distances is improved through regeneration, in contrast to the amplification techniques required for analog transmission. [Ref. 22: pp. 74-5]

Reliability may be defined as a network's ability to perform an intended function with predefined conditions over a stated time period. [Ref. 23: p. 441] A network may be considered reliable if it provides uninterruptible, error-free service. To a large extent, reliability is designed into a network by providing for alternative routing schemes and back-up equipment. [Ref. 24: p. 208]

Usually associated with reliability, is the accuracy of information transmission. Accuracy is typically an

assessment of performance, and is often measured as a ratio of error-free service to total service.

D. TRANSPARENCY

Another goal of ISDN is that information transfer should be transparent to the user. Transparent network operation is invisible to the user. [Ref. 24: p. 208] It allows subscribers to view the network as a 'black box' which provides transmission from terminal to terminal in a transparent mode. [Ref. 6: p. 10]

E. ECONOMY

Network economy may be defined as minimum overhead cost with efficient use of the transmission media. [Ref. 24: p. 208] According to Stallings, the principal economic benefits of an ISDN are related to cost savings and flexibility. The combination of voice and non-voice functions, or services, integrated on a single transport system enables the user to satisfy multiple requirements and only be charged for a single access line. Additionally, the services purchased can be more easily adapted to meet the user's needs. [Ref. 10: p. 543] Stallings further states that, "The efficiencies and economies of scale of an integrated network allow these services to be offered at lower cost than if they were provided separately." [Ref. 10: p. 543]

As stated by ITT's Gimpelson, Kimbleton, and Wang, [Ref. 25: p. 194]

> "The eventual growth of the ISDN will depend upon whether the marginal cost of adding a diversity of data services to the digital voice (telephone) network is less than the total cost of carrying such services on separate data networks. In such a comparison, either equal service quality must be offered for both schemes or the economics of the ISDN must be so attractive that end-users are willing to supply the means for attaining acceptable service....Studies of integrating data services on digital networks (IDN's) have shown that...ISDN operation has a marked economic advantage over multiple single-service networks."

F. CONVENIENCE

Network convenience may be defined as "the ease with which the user can gain access to and make use of a network." [Ref. 24: p. 211] Users may consider the ISDN as a "future telecommunications shopping center," with its efficient, easy access and multiple services conveniently combined under a common roof. [Ref. 5: p. 12] ISDN, like a shopping center, will have the flexibility to satisfy a variety of user needs and to adapt to changing customer and industry demands.

G. SECURITY

ISDN users must have a form of security protection that will prevent unauthorized access to critical databases and protect voice services from monitoring. The implementation, however, may occur within the user-supplied terminal equipment. Link security would be carrier controlled and end-to-end security managed on an individual call basis

through the signaling capability of the D channel. [Ref. 26: p. 2-28]

Security must be defined in terms of a user's needs. Network information must be protected from undesired disclosure. [Ref. 24: p. 211] Security on a network should be directed at controlling access to the terminal and access to the information being transmitted. Finally, encryption techniques "can be readily applied to digital data and analog data that have been digitized." [Ref. 10: p. 39]

H. TRANSITION

It is expected that ISDN's will evolve smoothly from concepts developed for telephone IDN's. This transition would progressively incorporate additional functions and network features in a way that provides for both existing and new services. Other factors which will impact on the timing of the transition are regulatory, competitive, geographical, and economic environments, and technology and interpretation of standards. [Ref. 5: p. 12]

A major change in telecommunications, such as ISDN, will impact not only large commercial customers, but also personnel within those establishments and eventually, the residential users. A staged implementation of ISDN would permit the smooth transition through the gradual introduction of both equipment and technology. [Ref. 27: p. 125]

The existing telecommunications network is based on the plain old telephone service (POTS), a typically reliable fully developed analog telephone network which can carry small amounts of data traffic which has been transformed from digital to analog. Fully developed telex networks and a variety of developed data networks exist via the POTS. There are also some developing IDN's. [Ref. 12: p. 21]

These networks will coexist during the transition phases, but their relative importance will change as the IDN's are developed and replace the analog networks. The IDN's will be enhanced with ISDN capabilities to provide other services such as videotex and teletex. It is possible that some current data networks may achieve access to ISDN via local exchanges. [Ref. 12: p. 21]

No one can predict the actual time line for development of the above scenario. The evolution from the development of IDN's will extend to ISDN capability enhancements of IDN's and will include provisions for existing data networks. [Ref. 12: p. 21]

I. OPERATION

As the existing networks develop into IDN's, then add increased enhancement capabilities, early ISDN's will be formed. Multiple ISDN's will most likely evolve within separate national boundaries, but will be viewed by the user as a single worldwide ubiquitous communications system.

A user will access an ISDN 'digital pipe' through a standardized interface (terminal equipment) and a customer access loop. The digital pipe is connected to an ISDN central, or service, office (a switch), which can access a 'core' network carrying a variety of network services. Circuit or packet switching options will be available and private and other networks can be accessed, as well as databases requiring broadband signals. [Ref. 28: p. 64]

Signaling for the user-network loop will be through the basic service, with two transmission channels and one channel for control signals (2B+D). [Ref. 28: p. 64] Network signaling will be accomplished through common channel signaling, where the control signals for the various services are carried on a single common channel. [Ref. 13: p. 614] Intelligence functions are required throughout the network.

As shown by Figure 5-1, the core network of the ISDN is accessible by each user through a local loop. The core network combines the capabilities of the sub-networks, allowing all of the services to be accessed by individual users. The single core network will evolve from the separate sub-networks through the application of international standards for connection of equipment to the network. [Ref. 28: p. 66]

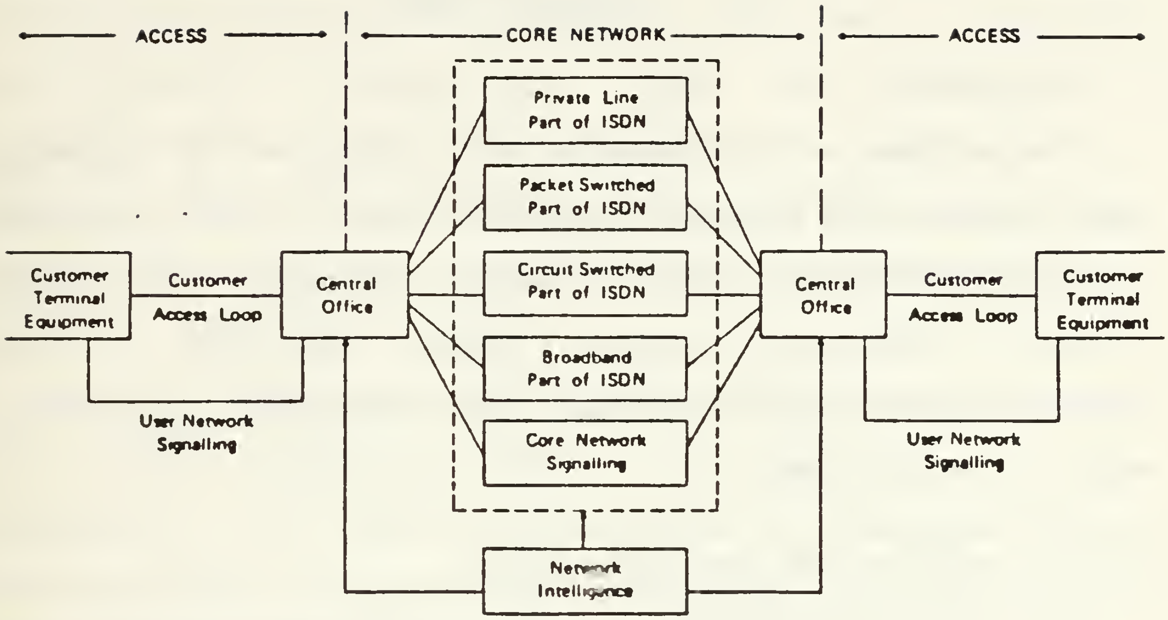


Figure 5-1 Basic ISDN Configuration

VI. A MODEL NETWORK

A. PURPOSE

The purpose of this chapter is to discuss an existing model integrated digital network in terms of the conceptual framework developed in the previous chapters. The model network, Information Network System (INS), is a pilot program of the Nippon Telegraph and Telephone Corporation (NTT) of Tokyo, Japan.

B. INS DESCRIPTION AND OBJECTIVES

INS is intended to be a nationwide, integrated services digital telecommunication facility. It is anticipated to be the nucleus for the future telecommunications services of the advancing information society in Japan. Its technologies include digital optical fiber and satellite communications. [Ref. 29: p. 64]

The intention of the INS model is to include a variety of both residential and commercial users from suburban and central Tokyo. The major objective of INS is to "provide people with a variety of cheaper, more convenient and more diversified telecommunications services." [Ref. 29: p. 64]

C. SYSTEM CONFIGURATION

The INS model system, which was constructed as a pilot plant, began subscriber operations on 28 September 1984,

after two years of facilities and equipment testing. The model utilizes current facilities in the Mitaka exchange (suburban Tokyo) to support offices, factories, administrative organizations, shops, and residences. A second section of the plant is located in a small area of central Tokyo to model communications between the headquarters offices in that area with the branches in the suburbs. [Ref. 30: p. 64]

As currently configured, the INS serves approximately 400 digital telephone sets, 1100 non-voice digital terminals, and 9000 analog terminals or telephones, served by INS digital local switching equipment. [Ref. 30: p. 66] The testing of the large number of analog telephone systems will provide valuable information for future conversion from analog to digital systems. This is important because of the existing large number of analog telephones. [Ref. 29: p. 70]

The non-voice facilities include digital facsimile terminals, digital interactive videotex terminals and broadband terminals. These terminals are expected to play the most important role in the model system. [Ref. 29: p. 70]

The INS model system configuration is shown in Figure 6-1. [Ref. 29: p. 64] The major analog portion of the network, the existing analog telephone network, is indicated along the top of the figure. As it is phased into the

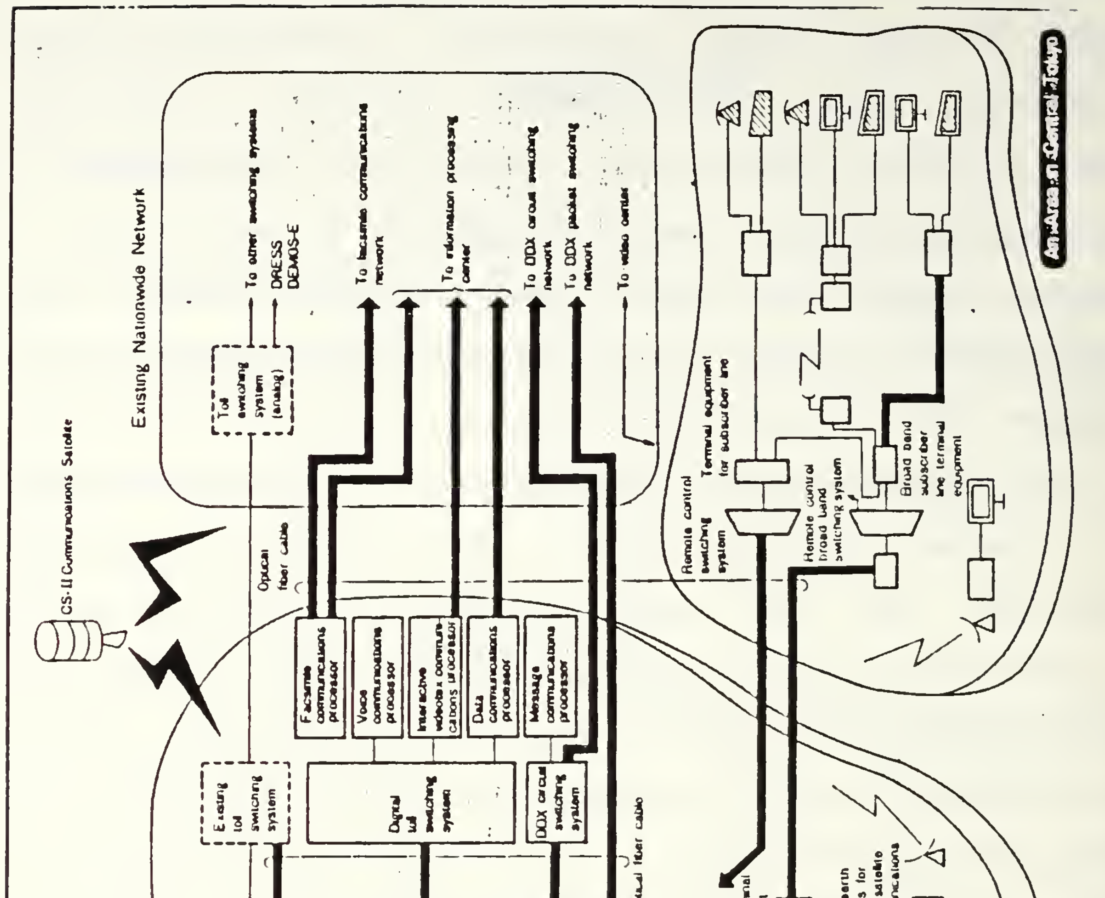


Figure 6-1 INS Model System Configuration.

integrated digital network through the INS, the IDN phase in the evolution will be complete. The INS enhancements parallel those which would be expected in an IDN, as it evolves toward an ISDN. [Ref. 29: p. 68]

The services and terminal equipment interfaces for the Mitaka area are indicated along the left side of Figure 6-1, and those for the Tokyo section, along the bottom right. The offices designated by dotted boxes correspond to the "Central Offices" in Figure 5-1, and interconnect by matching the directional arrows. With the exception of the broadband section, indicated along the bottom of Figure 6-1, the box labeled "Existing Network" is the "Core Network" described in Chapter V. The users accessing the broadband services would comprise a special sub-network of the INS.

By envisioning a mirror-image of the Mitaka area portion of Figure 6-1, a correspondence with the configuration in Figure 5-1 could be obtained. The INS is utilizing the most modern technology to realize a "fully digitalized end-to-end connection...between subscriber equipment through the whole network." [Ref. 29: p. 68] NTT feels that this may be the first time such a system is operated as a public network "anywhere in the world." [Ref. 29: p. 68]

D. SUPPORT TECHNOLOGIES

The support technologies utilized in the INS model system include new techniques for terminal, switching, transmission, and broadband communications. The hardware

involved includes digital telephones with signal conversion circuitry, terminal control equipment, transmission and signaling information channels (B+D), videotex terminals, video terminals, and miscellaneous processors. [Ref. 29: p. 74]

E. COMPARISON WITH ISDN CONCEPTUAL FRAMEWORK

Standardization of equipment interfaces was independently determined by NTT, because the CCITT standards had not been agreed upon within the time frame necessary to commence INS configuration planning. Because of the relatively small-scale size of the pilot plant and the fact that equipment was centrally managed and provided by NTT, problems with standardization have been avoided. Upon completion of the model plan and after full-scale implementation is underway, problems with standardization may become more prevalent. [Ref. 30: p. 66]

The INS model system is based on established digital technologies and systems. As such, reliability should be within system design objectives. However, since the model plan has only been operational since September, 1984, performance history and activity statistics are not yet available. INS planners hope the model will provide "technical data and responses from users and maintenance personnel." [Ref. 30: p. 66]

Transparency requirements are the same as for ISDN. The user is insulated from the technical aspects of digital

transmission. There is no need or requirement for the user to be concerned with the transmission functions of the network; the only concern is that the particular desired service is available when needed.

An objective of the INS planners is to provide less expensive telecommunications. There is still some question, however, if, in fact, society really wants and will pay for the services an ISDN or INS, in particular, will provide. [Ref. 30: p. 64] In order to align price of services received with cost of services provided, the INS will incorporate a bit-rate tariff scheme. [Ref. 30: p. 66] This scheme follows the ISDN concepts of charging for capacity rather than connect time and insuring that one type of service does not subsidize the cost of providing another service. [Ref. 10: p. 543]

While the ISDN focus is on easy user access and compatibility, the INS "places more emphasis on usefulness to the user." [Ref. 30: p. 66] The variety of terminal services are designed for convenience of both the residential and commercial users.

Security features of INS have not been addressed in the available literature. It may be assumed, however, that sufficient security measures have been taken and are well supported through the use of digital end-to-end connectivity, as in ISDN.

Implementation of INS will follow a gradual process while maintaining existing telecommunications services. [Ref. 29: p. 68] The existing telephone network will be digitized gradually "on a replacement basis when the service life of existing facilities expires." [Ref. 31: p. 81] This parallels the ISDN plan for transition from IDN through ISDN-capable enhancements.

F. SUMMARY

NTT has devised an integrated digital telecommunications model system. This model system should provide valuable information as INS evolves toward a full-scale ISDN. Other ISDN planners will benefit from the lead taken by NTT in its development of INS.

VII. ISDN CONSIDERATIONS FOR DOD

A. INTRODUCTION

This chapter will present areas of consideration for ISDN development relating to non-tactical Department of Defense (DoD) communications. Discussion will be limited to general conceptual considerations without identification of specific applications.

The ISDN concept is being developed worldwide and represents the state-of-the-art technologies in digital transmission, switching, signaling, and network management. To avoid duplication of effort, it is important that the evolving ISDN developments be closely monitored for potential crossover DoD applications.

B. ISDN FEATURES APPLIED TO DOD

This section will present features of the ISDN conceptual framework as applied to DoD. The features discussed are standardization, reliability, transparency, economy, convenience, security, and transition.

The ISDN standardization objective that calls for a single set of ISDN standards to permit universal access and the development of cost effective equipment could prove beneficial to DoD. Standards supporting universal access offer worldwide interoperability and interconnectivity, which are features important for DoD operation. It is

important that the DoD maintain representation on the various standards committees during ISDN development so that requirements of the DoD are included.

Because of the improved technologies involved in transmitting digital vis-a-vis analog signals, a digital based system, such as ISDN, should prove more reliable over time. The DoD depends on reliable systems for survivability not only in times of conflict, but also for routine operations.

Transparency must be viewed from within the DoD from different perspectives. For most routine administrative communications, it is usually not necessary that the user understand the mechanics of the network. However, for the more sensitive communications which support mission operations, the 'black box' approach may not be as readily acceptable.

Currently, ISDN is being undertaken primarily by telephone companies worldwide. Significant amounts of time and money have been expended on research and development. The DoD could benefit from evolving ISDN technologies without necessitating duplication of development effort. It is likely that there will be many DoD applications to which commercially available products and services of ISDN may be adapted for use. Examples of these applications may include facsimile machines and digital voice services. To the extent that commercial technologies and services can satisfy

the specialized needs of the DoD, they should be appropriately considered as alternatives in procurement or in-house development decisions.

The convenience of an ISDN system is that many services are readily available for the user. Services such as voice, information transfer, and facsimile can be of immediate use to the DoD. In the opinion of the author, future developments such as teletex, videotex, and video teleconferencing should have promising DoD applications. As examples, many routine administrative functions could be expedited and some personnel travel could be eliminated.

In any DoD communications system, security is important. In a network such as ISDN which can be accessed by many different types of users, the specialized security needs of the DoD must be appropriately considered. Encryption of digitized signals can be accomplished at the digital interface, which may be a user terminal. The integrated voice/data capabilities of ISDN should provide a "faster, more comprehensive means of establishing secure connections separately from the [existing] talk-path which carries encrypted information." [Ref. 26: p. 2-28]

Any evolution toward ISDN should be gradual. Any large scale movement toward ISDN by the DoD would be subjected to the same Program Objective Memorandum (POM) and budget reviews as other major new program initiatives. There is a considerable amount of lead time involved in these reviews,

and program initiatives must compete for limited resources. Accordingly, it is important that any ISDN program initiatives have the top level support required to survive the POM and budget review cycles. A successful transition to ISDN would require an early commitment from top command levels.

In addition to the budget and procurement lead times involved in transition to ISDN, there would be additional lead time involved in installation of the new supporting technologies. The long lead time does provide the opportunity to effect an orderly transition. As an example, older equipment can be replaced as necessary with newer digital components, similar to NTT's program for the INS.

C. CONCEPTUAL MILITARY ISDN

To begin to envision an ISDN for the military, it is possible to accept an initial concept, then adapt it to the special requirements of the military. Aspects of some existing networks would merge nicely with some IDN or ISDN capabilities.

The Automatic Digital Network (AUTODIN) II has been replaced by the Defense Data Network, DDN, a system based on technology developed from the Advanced Research Projects Agency Network, ARPANET. The DDN is a "single, integrated packet switching network designed to meet the data communications requirements of the DoD." [Ref. 32: p. 5] The DDN is evolving in stages as a combination of several

other military networks, and began the process of implementation throughout the DoD in February, 1984. Plans call for the ability to transmit classified information on a sub-network of the DDN. [Ref. 32: p. 21]

The DDN is a visible, operational network which could be included as a "Service" or "Other Network" (sub-network) in the "Core Network" described in Figure 5-1. This could be the first step toward a DoD ISDN.

The DDN was designed solely for data transmission. A possible IDN enhancement would be development of a digital voice telephone to interface with the DDN. A form of 'digital pipe' theoretically exists for the DDN, which could be upgraded to include the voice services, such as enhancements or replacements for the commercial, Automated Voice Network, (AUTOVON), and Federal Telecommunications System (FTS) services now available. Another IDN or ISDN service immediately useful to the DoD is facsimile, which is currently operational, for example, in the INS model system, using digital broadband high speed terminals. [Ref. 30: p. 67]

The DDN terminals are standardized for the ARPANET, and would require adaptation to whatever ISDN standards are developed. There are many other features of the ISDN and IDN, mentioned in the previous section, that could prove beneficial for use in the DoD. Security, reliability, and economy are perhaps the most important features for a DoD

ISDN. Such a system should be evaluated as a viable alternative to the current plans for upgrade and replacement of the existing systems.

D. SUMMARY

The DoD can benefit greatly both from the evolving technologies supporting ISDN and from implementation of an ISDN. The DDN is an existing system which could be gradually enhanced to evolve into an IDN, and later, an ISDN.

Among the most important features of ISDN for the DoD are security, reliability, and economy. It is in the best interest of the DoD to remain abreast of ISDN developments as technologies improve and costs decrease as expected. ISDN's potential for improved worldwide connectivity and interoperability of communications systems, especially in times of conflict, makes it a viable system, worthy of careful consideration by DoD.

VIII. UNRESOLVED ISSUES AND SUMMARY

A. INTRODUCTION

The major unresolved issues surrounding ISDN pertain to standardization. Because ISDN is a global initiative, many different countries, committees, and groups are involved in its evolution. Also, the needs of equipment manufacturers, telecommunications vendors, and commercial and residential users must be considered. As a result, standardization has been a difficult objective to achieve.

Other ISDN issues addressed include economic and tariff considerations. These issues will be discussed only to the degree necessary to provide the reader with an awareness of their existence.

B. STANDARDIZATION ISSUES

As stated in Chapter II, a single set of ISDN standards is necessary for universal access and cost-effective equipment development. [Ref. 10: p. 540] The CCITT is continuing discussions on the issues of standardization. Among these issues are concerns about the location of the line of demarcation between the network and the user interface. The Federal Communications Commission (FCC) has ruled that the network termination 'box,' discussed in Chapter V, is part of the customer premises equipment and not part of the public network. This has placed the U.S. in

a position that is at variance with the CCITT draft recommendations which state that the 'box' is the network termination. It has been argued that the FCC ruling "will inhibit introduction of new services because it makes standards setting particularly difficult." [Ref. 20: p. 47] If standards cannot be reached, end-to-end network compatibility will suffer. The establishment of worldwide standards for ISDN will not be possible until this dispute is resolved.

Even with the open architecture planned for the ISDN, problems exist in pro-competitive environments, such as the United States. Among the objectives of the ISDN, as stated in Chapter II, is the U.S. requirement that "certain enhanced services be offered competitively." [Ref. 10: p. 540] Competition within the enhanced services should not interfere with the provision of the basic network services. Figures 8-1 and 8-2 contrast ISDN's in noncompetitive and competitive environments. [Ref. 10: pp. 541-2]

C. ECONOMIC AND TARIFF ISSUES

A basic economic question with ISDN is how it will pass the test of the marketplace. The test will ultimately be decided by the demand generated for ISDN services. There are substantial investment costs associated with the transition to digital technology. At issue will be whether the eventual market demand for ISDN will justify its investment costs.

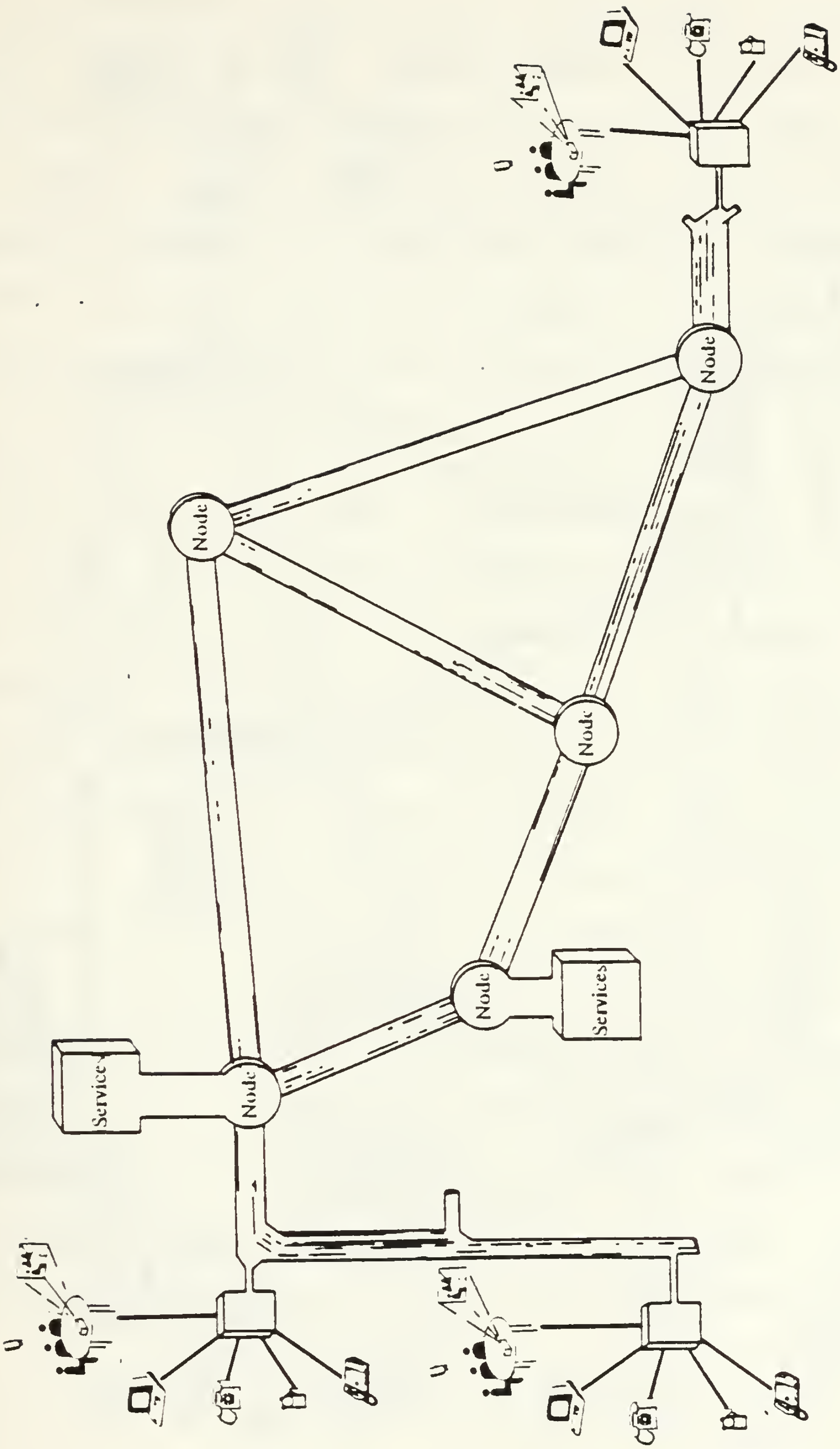


Figure 8-1 ISDN in a Noncompetitive Environment.

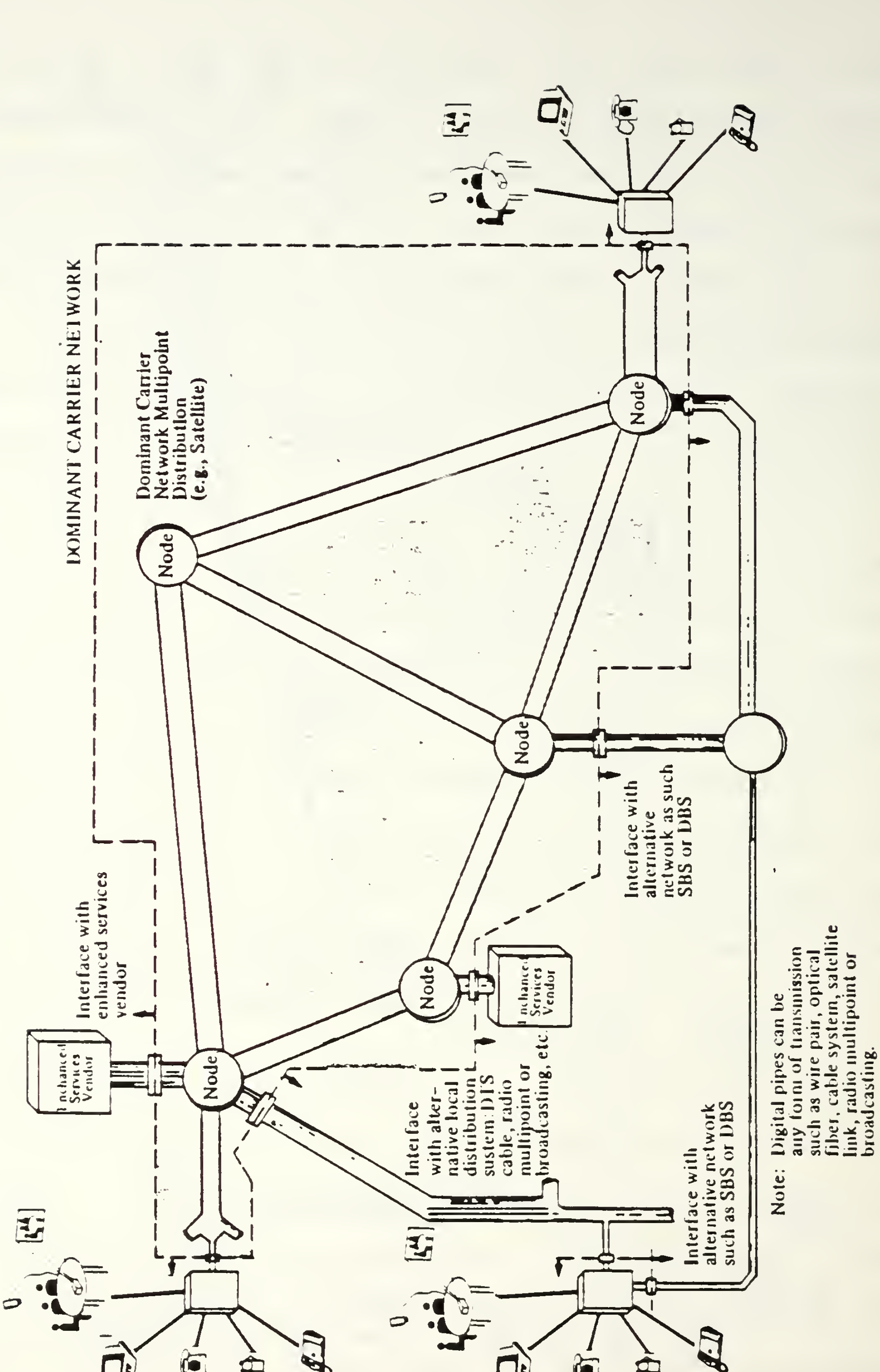


Figure 8-2 ISDN in a Competitive Environment.

It is presently unknown how tariffs will actually be assessed. Some advocates of ISDN support a bit-rate tariff, where the user charges are based on "capacity used rather than connect time." [Ref. 10: p. 540] The NTT INS plan, discussed in Chapter VI, eventually intends to incorporate a bit-rate pricing scheme in its network. The impact of bit-rate pricing for ISDN services has yet to be determined.

D. SUMMARY

There are no true ISDN's in operation today. Evolution toward ISDN as at different stages in different countries. Some countries, particularly Japan and Canada, have demonstrated a commitment to an evolution toward ISDN.

There are potential applications for ISDN within DoD. Primary benefits to the DoD of an ISDN include security, reliability, and economy. It is possible that an existing DoD system, the DDN, could be enhanced with IDN/ISDN features. Future long range plans of the DoD should include appropriate considerations for IDN and ISDN developments.

The future of ISDN will be heavily dependent upon the acceptance of universal standards. It is necessary for a consensus to be reached soon to permit carriers, manufacturers and users to adapt to the ISDN evolution.

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